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FAR-INFRARED ab PLANE REFLECTANCE AND TRANSMISSION OF $Bi_2Sr_2CaCu_2O_8$

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We review recent experimental data on the infrared thin film transmission and single crystal reflection spectra of $Bi_2Sr_2CaCu_2O_8$ ($T_c \approx 85$ K). Both show that the low frequency response can be described by a Drude absorption with a relaxation rate for the carriers of the order of 100 cm^{-1}. This places the materials in the clean limit and no superconducting gap structure is evident. A temperature independent midinfrared absorption is present with a sharp onset at 300 cm^{-1}.

1. INTRODUCTION

We present here measurements of the far-infrared transmission and reflectance of $Bi_2Sr_2CaCu_2O_8$ the 85 K superconductor.[1] Of special interest is a comparison of this newer material with $YBa_2Cu_3O_7$ which has a broad Drude band in the far infrared that overlaps the temperature independent midinfrared band that peaks at 1000 cm^{-1}. In contrast the scattering rate in most samples of $Bi_2Sr_2CaCu_2O_8$ is low and the onset of the midinfrared band higher in frequency leading to a clearer separation of the two bands.[2]

2. SINGLE CRYSTAL REFLECTANCE

Figure 1 Shows the reflectance of one of the better single crystal samples with a T_c of 85 K and width (10–90 %) of 8 K. Other samples show a background absorption of several percent in the 50 – 300 cm^{-1} region, possibly due to a non-superconducting metallic surface layer. In the superconducting state the reflectance of a good sample is essentially unity up to 300 cm^{-1} and then drops rapidly to 90 % at 700 cm^{-1}. While this behavior is reminiscent of a superconducting gap, in this case it is clear from the curve labelled N, taken at 100 K well above T_c that the gap structure is also present in the normal state.

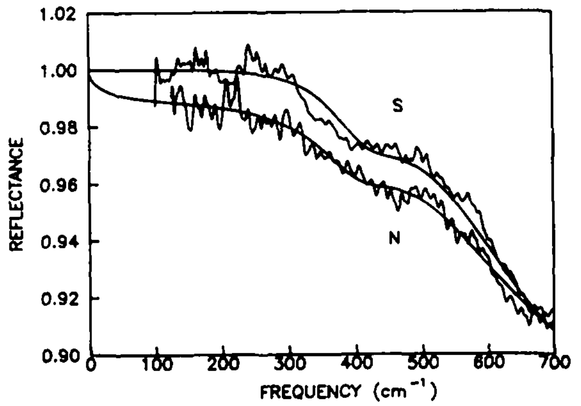

Figure 1

The reflectance of $Bi_2Sr_2CaCu_2O_8$ at 100 K marked (N) and at 1.2 K marked (S). The smooth lines are fits to a model that has a Drude free-carrier term and three broad oscillators. The superconducting-state curve is generated by narrowing the normal state Drude term to a delta function.

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Kramers Kronig analysis of the reflectance yields the optical conductivity, that at low frequency is dominated by the very prominent Drude band. The peak can be fit with a plasma frequency of 11 600 cm^{-1} (1.44 eV) and a relaxation rate of 70 cm^{-1}. The calculated dc resistivity is 33 $\mu\Omega$cm.

Above 300 cm^{-1} the conductivity has a peak centered at 400 cm^{-1} which, in the superconducting state, becomes clearly resolved. A second peak appears above 600 cm^{-1}. If we assume that the reflectance is unity below 300 cm^{-1} we obtain a gap in the conductivity of this magnitude. A more conservative estimate would be to assume that the 100 % reflectance line has a 0.5 % error associated with it. In that case the sharp gap broadens to form a more gradual threshold without a true gap.

3. THIN FILM TRANSMISSION

Transmission experiments on superconductors require films that are a few hundred Å in thickness, on substrates that are transparent to infrared and suitable for epitaxial growth. We present here temperature dependent transmission spectra for 200 Å rf magnetron sputtered films of the $Bi_2Sr_2CaCu_2O_8$ compound on MgO substrates.[3] The reststrahlen band of MgO is at 350 cm^{-1} and restricts measurements to frequencies below 300 cm^{-1} . The films were oriented with their c-axes perpendicular to the substrate. They exhibited an onset temperature of 85 K with a transition width of 10 K.

Figure 2 shows the transmission spectra of a $Bi_2Sr_2CaCu_2O_8$ film for temperatures above and below T_c referenced to an MgO substrate. The transmission increases monotonically with frequency. The onset of superconductivity is characterized by a sharp drop below T_c in transmittance at low frequencies and a modest rise at high frequency. The crossover where the normal state and superconducting states have equal transmission occurs near 180 cm^{-1}. We measured several additional samples which showed qualitatively similar behavior.

None of the samples has the behavior expected for a conventional superconductor: zero transmission when

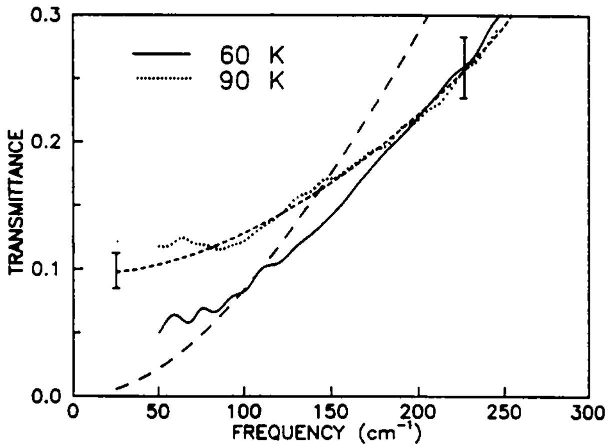

Figure 2

Far-infrared transmittance of a 200 Å film of $Bi_2Sr_2CaCu_2O_8$ for temperatures above and below T_c. The dotted and solid lines are the experimental transmission. The curve with the short dashes is a least squares fit to a simple Drude model. The error bars shown demonstrate the effect of varying the dc conductivity by ± 10 % (low frequency error bar) and the effect of varying the relaxation rate by the same amount (high frequency error bar). The superconducting calculation (long dashes) is in the clean limit.

extrapolated to zero frequency. This discrepancy may arise from the presence of non superconducting material within the sample.

A fit to the 90 K data using a simple Drude model (shown as a dashed curve in Fig. 2) gives a plasma frequency (ω_p) of 10500 cm^{-1}, a relaxation rate ($1/\tau$) of 165 cm^{-1} and a dc resistivity of 90 $\mu\Omega$cm. These results show reasonable agreement with dc resistivity[4] and the reflectance measurements. The relaxation rate of the crystal is lower in comparison to the thin film.

The dashed curve in figure 2 shows the expected transmission for a BCS superconductor with a normal state relaxation rate of 25 cm^{-1}. The fit to the experimental 60 K curve is poor and the task of extracting any gap from the measurements very dubious.

REFERENCES

(1). H. Maeda et al. Jpn. J. Appl. Phys. Lett. 27, (1988) L209.
(2). M. Reedyk et al. Phys. Rev. B38, (1988) 11981.
(3). J.J. Yeh et al. App. Phys. Lett. 54, (1989), 377
(4). S. Martin, et al. Phys. Rev. Lett. 60, (1988) 2194.